

# LM3525

## Single Port USB Power Switch and Over-Current Protection

### General Description

The LM3525 provides Universal Serial Bus standard power switch and over-current protection for all host port applications. The single port device is ideal for Notebook PC and Handheld PC applications that supply power to one port.

A 1 ms delay on fault flag output prevents erroneous over-current reporting caused by inrush currents during the hot-plug events.

The LM3525 accepts an input voltage between 2.7V and 5.5V allowing use as a device-based inrush current limiter for 3.3V USB peripherals, as well as Root and Self-Powered Hubs at 5.5V. The Enable input accepts both 3.3V and 5.0V logic thresholds.

The small size, low  $R_{ON}$ , and 1 ms fault flag delay make the LM3525 a good choice for root hubs as well as ganged power control in space-critical self-powered hubs.

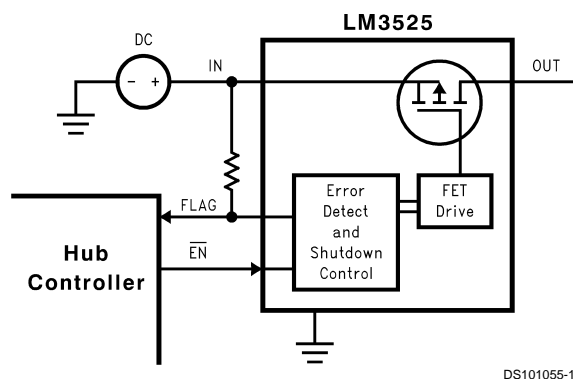
### Features

- 1 ms Fault Flag Delay During Hot-Plug Events
- Smooth Turn-On Eliminates Inrush Induced Voltage Drop
- UL Recognized Component: REF # 205202
- 1A Nominal Short Circuit Output Current Protects Notebook PC Power Supplies
- Thermal Shutdown Protects Device in Direct Short Condition
- 500mA Minimum Continuous Load Current
- Small SO-8 Package Minimizes Board Space
- 2.7V to 5.5V Input Voltage Range
- Switch Resistance  $\leq 120 \text{ m}\Omega$  Max. at  $V_{IN} = 5\text{V}$
- 1 $\mu\text{A}$  Max Standby Current
- 100  $\mu\text{A}$  Max Operating Current
- Undervoltage Lockout (UVLO)

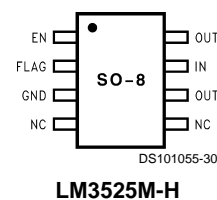
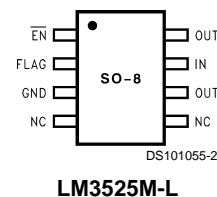
### Applications

- Universal Serial Bus (USB) Root Hubs including Desktop and Notebook PC
- USB Monitor Hubs
- Other Self-Powered USB Hub Devices
- High Power USB Devices Requiring Inrush Limiting
- General Purpose High Side Switch Applications

### Typical Operating Circuit and Connection Diagram



UL Recognized Component  
DS101055-31



## Ordering Information

Part Number	Enable, Delivery Option	Package Type
LM3525M-H	Active High Enable, 95 units per rail	SO-8, NS Package Number M08A
LM3525M-L	Active Low Enable, 95 units per rail	
LM3525MX-H	Active High Enable, 2500 units per reel	
LM3525MX-L	Active Low Enable, 2500 units per reel	

**Absolute Maximum Ratings** (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage	-0.3V to 6.0V
Output Voltage	-0.3V to 6.0V
Voltage at All Other Pins	-0.3V to 5.5V
Power Dissipation ( $T_A = 25^\circ\text{C}$ ) (Note 2)	700 mW
$T_{JMAX}$ (Note 2)	150°C

**Operating Ratings**

Supply Voltage Range	2.7 to 5.5V
Operating Ambient Range	-40°C to +85°C
Operating Junction Temperature Range	-40°C to +125°C
Storage Temperature Range	-65°C to +150°C
Lead Temperature (Soldering, 5 seconds)	260°C
ESD Rating (Note 3)	2 kV

**DC Electrical Characteristics**

Limits in standard typeface are for  $T_J = 25^\circ\text{C}$ , and limits in **boldface** type apply over the full operating temperature range. Unless otherwise specified:  $V_{IN} = 5.0\text{V}$ ,  $\overline{\text{EN}} = 0\text{V}$  (LM3525-L) or  $\text{EN} = V_{IN}$  (LM3525-H).

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$R_{ON}$	On-Resistance	IN to Out pins $V_{IN} = 5\text{V}$ $V_{IN} = 2.7\text{V}$		80 120	120 160	m $\Omega$
$I_{OUT}$	OUT pins continuous output current		<b>0.5</b>			A
$I_{SC}$	Short Circuit Output Current	(Note 4)	0.5	1.0	1.5	A
$I_{LEAK}$	OUT pins Output Leakage Current	$\overline{\text{EN}} = V_{IN}$ (LM3525-L) or $\text{EN} = \text{GND}$ (LM3525-H),		0.15	10	$\mu\text{A}$
$OC_{THRESH}$	Over-current Threshold			2.25	3.2	A
$R_{FO}$	FLAG Output Resistance	$I_{FO} = 10\text{ mA}$ , $V_{IN} = 5\text{V}$		6	<b>25</b>	$\Omega$
		$I_{FO} = 10\text{ mA}$ , $V_{IN} = 2.7\text{V}$		8	<b>40</b>	
$I_{EN}$	$\overline{\text{EN}}/\text{EN}$ Leakage Current	$\overline{\text{EN}}/\text{EN} = 0\text{V}$ or $\overline{\text{EN}}/\text{EN} = V_{IN}$	-0.5		0.5	$\mu\text{A}$
$V_{IH}$	$\overline{\text{EN}}/\text{EN}$ Input Voltage	(Note 5)	<b>2.4</b>	1.9		V
$V_{IL}$	$\overline{\text{EN}}/\text{EN}$ Input Voltage	(Note 5)		1.7	<b>0.8</b>	V
$V_{UVLO}$	Under-Voltage Lockout	$V_{IN} = \text{Increasing}$ $V_{IN} = \text{Decreasing}$		1.9 1.8		V
$I_{DDOFF}$	Supply Current	Switch OFF		0.05	1	$\mu\text{A}$
$I_{DDON}$	Supply Current	Switch ON		65	100	$\mu\text{A}$
$Th_{SD}$	Overtemperature Shutdown Threshold (Note 4)	$T_J$ Increasing		135		$^\circ\text{C}$
		$T_J$ Decreasing		125		$^\circ\text{C}$
$I_{FH}$	Error Flag Leakage Current	$V_{FLAG} = 5\text{V}$		0.1	1	$\mu\text{A}$

## AC Electrical Characteristics

Limits in standard typeface are for  $T_J = 25^\circ\text{C}$ , and limits in **boldface** type apply over the full operating temperature range. Unless otherwise specified:  $V_{IN} = 5.0\text{V}$ .

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$t_r$	OUT Rise Time	$R_L = 10\Omega$		200		$\mu\text{s}$
$t_f$	OUT Fall Time	$R_L = 10\Omega$		20		$\mu\text{s}$
$t_{ON}$	Turn on Delay, $\overline{\text{EN}}$ to OUT	$R_L = 10\Omega$		200		$\mu\text{s}$
$t_{OFF}$	Turn off Delay, $\overline{\text{EN}}$ to OUT	$R_L = 10\Omega$		20		$\mu\text{s}$
$t_{OC}$	Over Current Flag Delay	$R_L = 0$		1		ms

**Note 1:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Electrical specifications do not apply when operating the device beyond its rated operating conditions. Products are not tested under negative Absolute Maximum conditions.

**Note 2:** The maximum power dissipation must be derated at elevated temperatures and is dictated by  $T_{JMAX}$  (maximum junction temperature),  $\theta_{JA}$  (junction to ambient thermal resistance), and  $T_A$  (ambient temperature). The maximum allowable power dissipation at any temperature is  $P_{DMAX} = (T_{JMAX} - T_A)/\theta_{JA}$  or the number given in the Absolute Maximum Ratings, which ever is lower. The thermal resistance  $\theta_{JA}$  of the LM3525 in the SO-8 package is  $150^\circ\text{C/W}$ .

**Note 3:** The human body model is a 100 pF capacitor discharged through a 1.5 k $\Omega$  resistor into each pin.

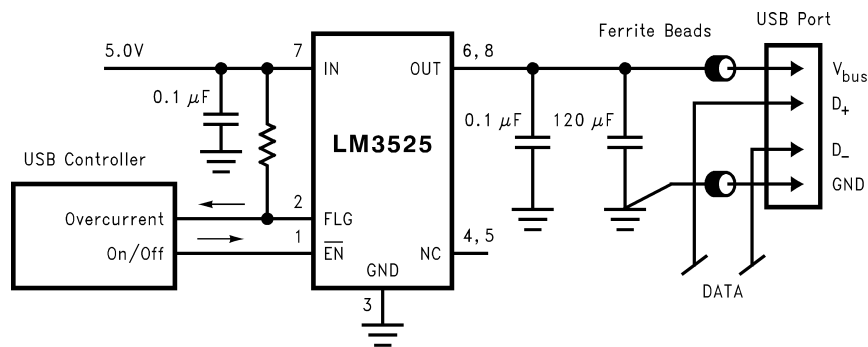
**Note 4:** Thermal shutdown will protect the device from permanent damage.

**Note 5:** For the LM3525-L, OFF is  $\overline{\text{EN}} \geq 2.4\text{V}$  and ON is  $\overline{\text{EN}} \leq 0.8\text{V}$ . For the LM3525-H, OFF is  $\text{EN} \leq 0.8\text{V}$  and ON is  $\text{EN} \geq 2.4\text{V}$ .

## Pin Description

Pin Number	Pin Name	Pin Function
1	$\overline{\text{EN}}$ (LM3525-L) EN (LM3525-H)	Enable (Input): Logic-compatible enable input.
2	FLG	Fault Flag (Output): Active-low, open-drain output. Indicates overcurrent, UVLO and thermal shutdown.
3	GND	Ground
4, 5	NC	Not internally connected.
7	IN	Supply Input: This pin is the input to the power switch and the supply voltage for the IC.
6, 8	OUT	Switch Output: This pin is the output of the high side switch. Pins 6 & 8 must be tied together.

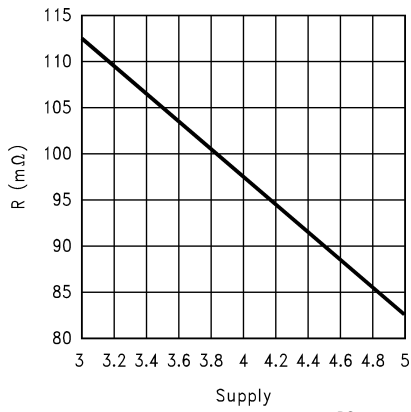
## Typical Application Circuit



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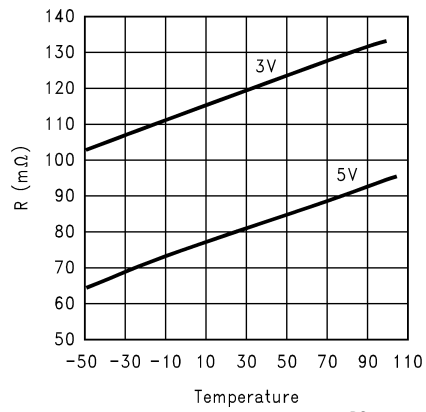
**Typical Performance Characteristics**  $V_{IN} = 5.0V, I_L = 500\text{ mA}, T_A = 25^\circ\text{C}$  unless otherwise specified.

**RDS<sub>ON</sub> vs V<sub>IN</sub>**



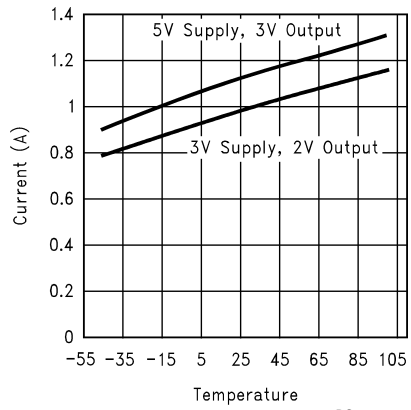
DS101055-4

**RDS<sub>ON</sub> vs Temperature**



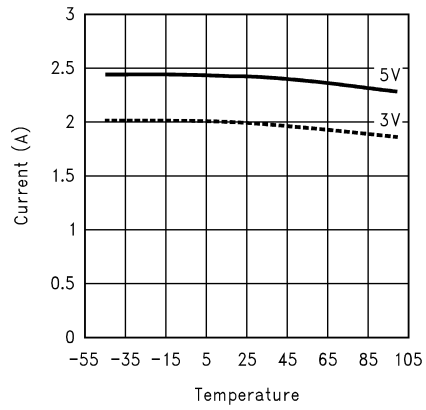
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**Current Limit vs Temperature**



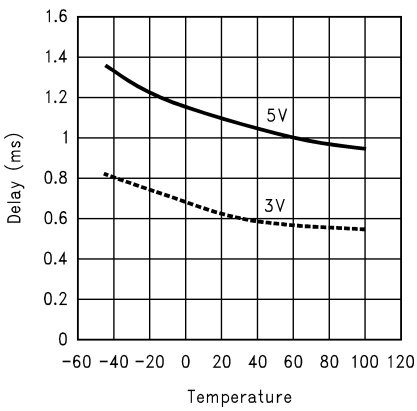
DS101055-6

**Over Current Threshold vs Temperature**



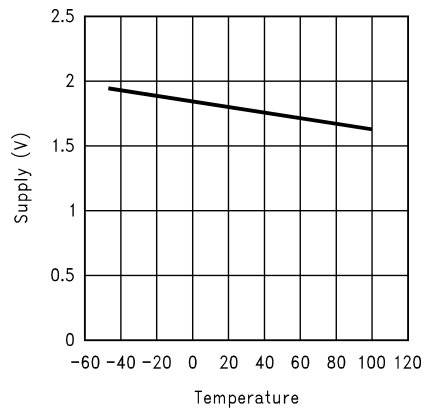
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**Delay vs Temperature**



DS101055-8

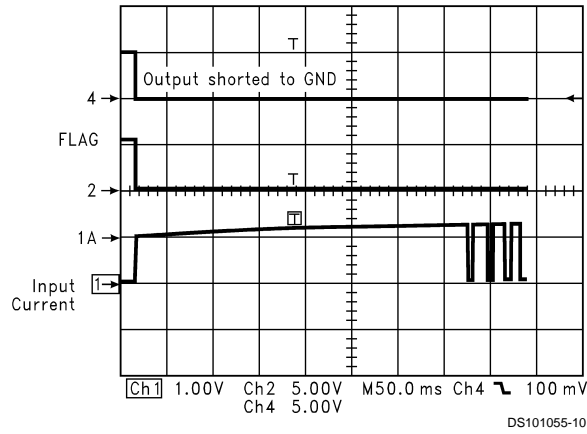
**UVLO Threshold**



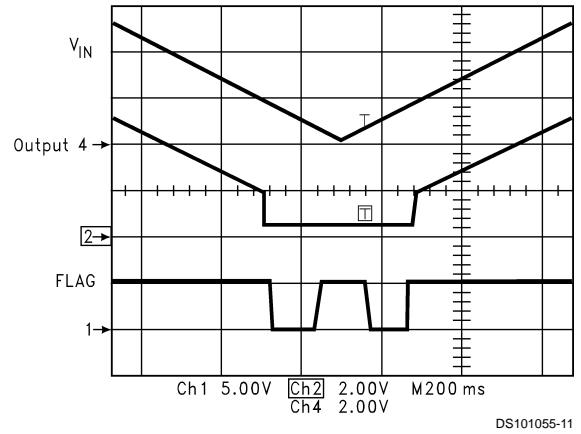
DS101055-9

# Typical Performance Characteristics $V_{IN} = 5.0V$ , $I_L = 500\text{ mA}$ , $T_A = 25^\circ\text{C}$ unless otherwise specified. (Continued)

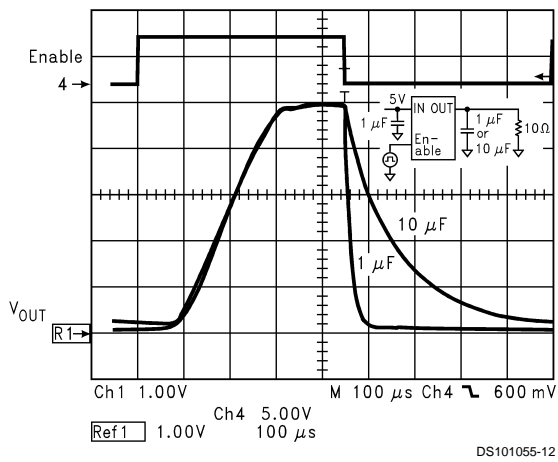
## Short Circuit Response



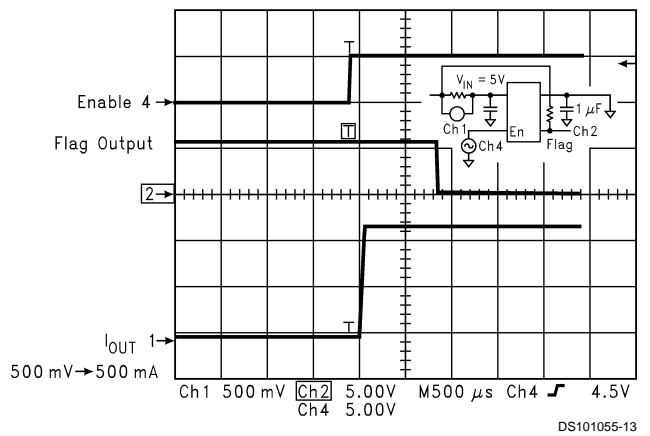
## Under Voltage Lock Out (UVLO)



## Turn-ON/OFF Delay and Rise Time/Fall Time



## Short Circuit Current



## Functional Description

The LM3525-H and LM3525-L are high side P-Channel switches with active-high and active-low enable inputs, respectively. Fault conditions turn off and inhibit turn-on of the output transistor and activate the open-drain error flag transistor sinking current to the ground.

### INPUT AND OUTPUT

IN (Input) is the power supply connection to the control circuitry and the source of the output MOSFET.

OUT (Output) is the drain of the output MOSFET. In a typical application circuit, current flows through the switch from IN to OUT towards the load.

If  $V_{OUT}$  is greater than  $V_{IN}$  when the switch is enabled, current will flow from OUT to IN since the MOSFET is bidirectional.

### THERMAL SHUTDOWN

LM3525 is internally protected against excessive power dissipation. In the event of a shorted output or heavy loads that could elevate the die temperature to above approximately 135°C, the thermal shutdown circuit of the LM3525 will be activated and the power switch turned off.

The switch is turned on after die temperature drops by 10°C. This built-in temperature hysteresis prevents undesirable oscillation of the thermal protection circuit and allows the device to reset itself after it is cooled down.

### UNDERVOLTAGE LOCKOUT

UVLO prevents the MOSFET switch from turning on until input voltage exceeds 1.9V.

UVLO shuts off the MOSFET switch and signals the fault flag if input voltage drops below 1.8V. UVLO functions only when device is enabled.

### CURRENT LIMIT

The current limit circuit is designed to protect the system supply, the MOSFET switches and the load from damage caused by excessive currents. The current limit threshold is set internally to allow a minimum of 500 mA through the MOSFET but limit the maximum current to 1.0A typical.

### FAULT FLAG

The fault flag is an open-drain output capable of sinking 10 mA load current to typically 60 mV above ground.

The fault flag is active (pulled low) when any of the following conditions are present: undervoltage, current limit, or thermal shutdown.

A 1ms delay in reporting fault condition prevents erroneous fault flags and eliminates the need for external RC delay network.

## Application Information

### FILTERING

The USB specification indicates that “no less than 120  $\mu$ F tantalum capacitors” must be used on the output of each downstream port. This bulk capacitance provides the short-term transient current needed during a hot plug-in. Current surges caused by the input capacitance of the downstream device could generate undesirable EMI signals. Ferrite beads in series with all power and ground lines are recommended to eliminate or significantly reduce EMI.

In selecting a ferrite bead, the DC resistance of the wire used must be kept to minimum to reduce the voltage drop.

A 0.01  $\mu$ F ceramic capacitor is recommended on each port directly between the  $V_{BUS}$  and ground pins to prevent EMI damage to other components during the hot - detachment.

Adequate capacitance must be connected to the input of the device to limit the input voltage drop during a hot-plug event to less than 330 mV. For a few tens of  $\mu$ s, the host must supply the inrush current to the peripheral, charging its bulk capacitance to  $V_{BUS}$ . This current is initially supplied by the input capacitor. A 33  $\mu$ F 16V tantalum capacitor is recommended.

In choosing the capacitors, special attention must be paid to the Effective Series Resistance, ESR, of the capacitors to minimize the IR drop across the capacitor's ESR.

### SOFT START

To eliminate the upstream voltage droop caused by the high in-rush current drawn by the output capacitors, the inrush current is internally limited to 1.0A.

### TRANSIENT OVER-CURRENT DELAY

In USB applications, it is required that output bulk capacitance is utilized to support hot-plug events. During hot-plug events, inrush currents may also cause the flag to go active. Since these conditions are not valid over-current faults, the USB controller must ignore the flag during these events.

High transient current is also generated when switch is enabled and large values of capacitance at the output have to be rapidly charged. The inrush currents created could exceed the short circuit current limit threshold of the device forcing it into the current limit mode. The capacitor is charged with the maximum available short circuit current set by the LM3525. The duration of the inrush current depends on the size of the output capacitance and load current. Since this is not a valid fault condition, the LM3525 delays the generation of the fault flag for 1 ms. If condition persists due to other causes such as a short, a fault flag is generated after a 1 ms delay has elapsed.

The LM3525's 1 ms delay in issuing the fault flag is adequate for most applications. If longer delays are required, an RC filter as shown in *Figure 1* may be used.

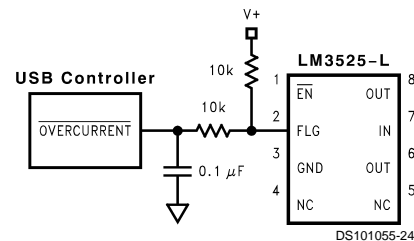


FIGURE 1. Transient Fitter

### PCB LAYOUT CONSIDERATIONS

In order to meet the USB requirements for voltage drop, droop and EMI, each component used in this circuit must be evaluated for its contribution to the circuit performance as shown in *Figure 2*. The PCB layout rules and guidelines must be followed.

- Place the switch as close to the USB connector as possible. Keep all  $V_{BUS}$  traces as short as possible and use at least 50-mil, 1 ounce copper for all  $V_{BUS}$  traces. Solder plating the traces will reduce the trace resistance.

## Application Information (Continued)

- Avoid vias as much as possible. If vias are used, use multiple vias in parallel and/or make them as large as possible.
- Place the output capacitor and ferrite beads as close to the USB connector as possible.

- If ferrite beads are used, use wires with minimum resistance and large solder pads to minimize connection resistance.

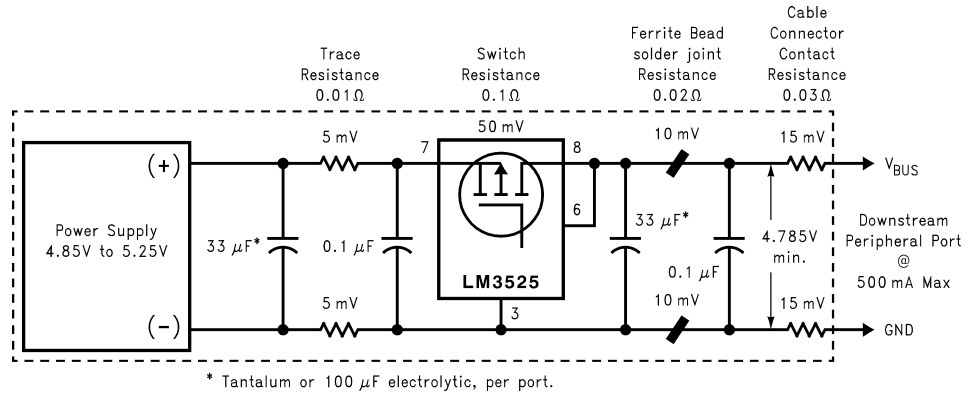


FIGURE 2. Self-Powered Hub Per-Port Voltage Drop



# Typical Applications

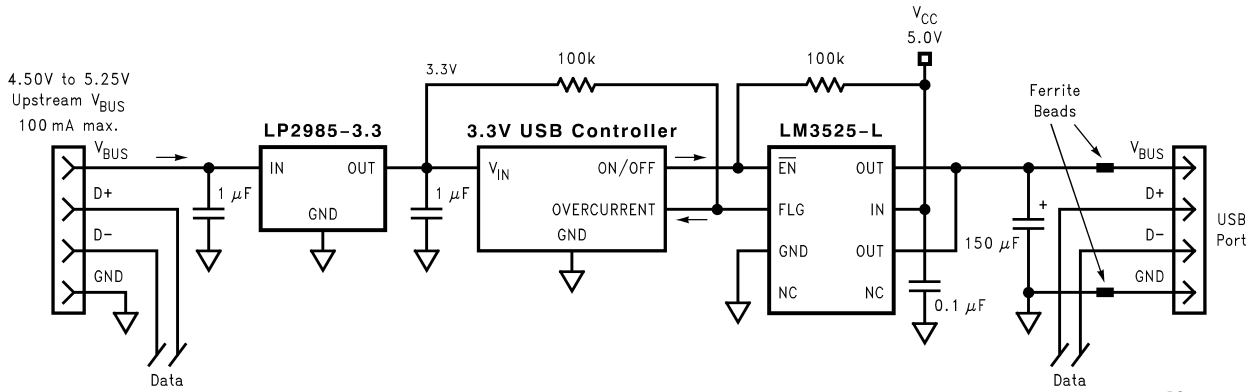


FIGURE 3. Single-Port USB Self-Powered Hub

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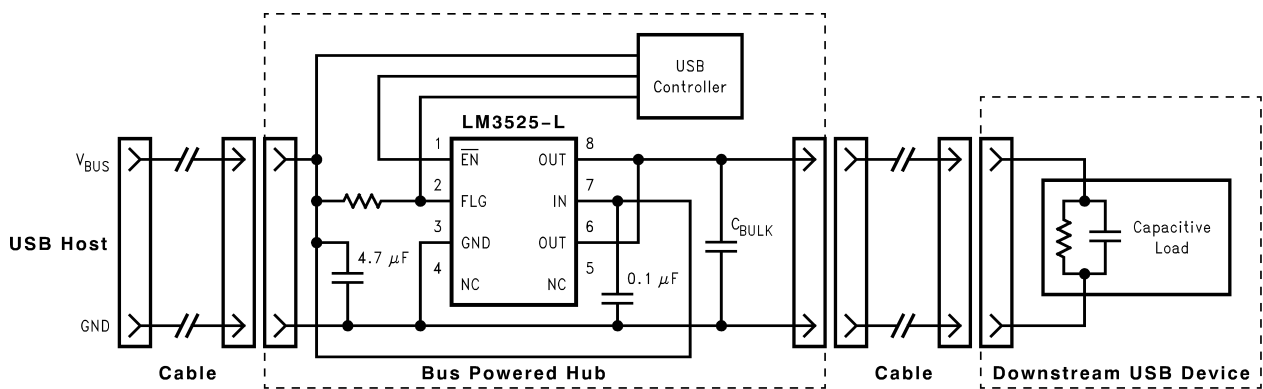


FIGURE 4. Soft-Start Application

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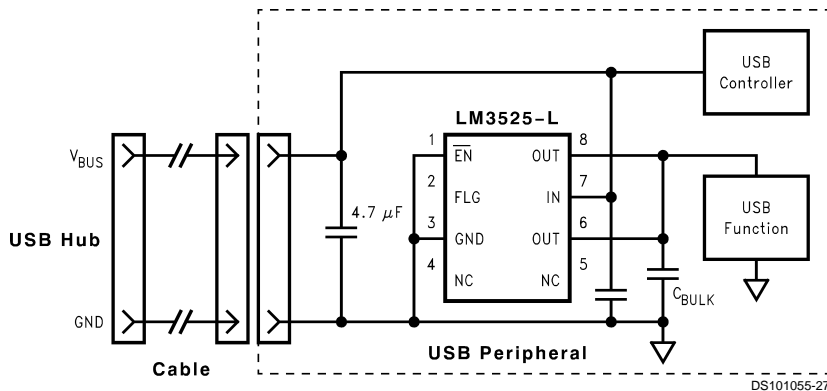
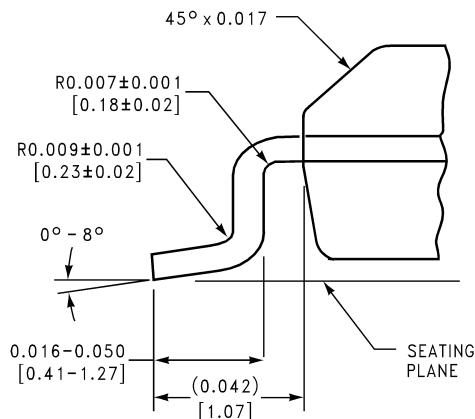
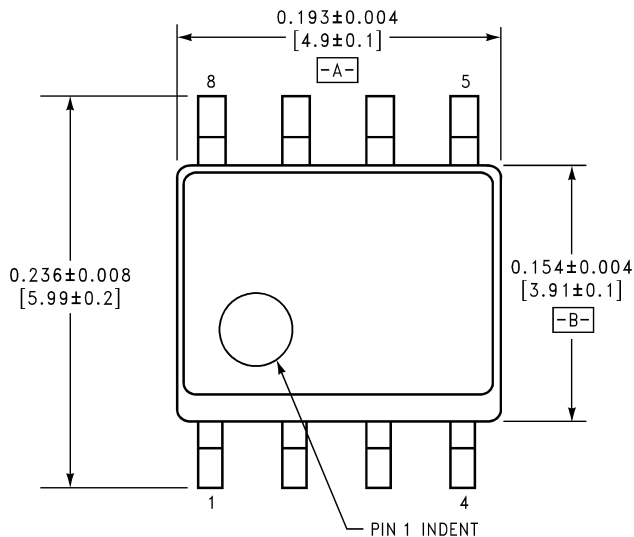


FIGURE 5. Inrush Current-limit Application

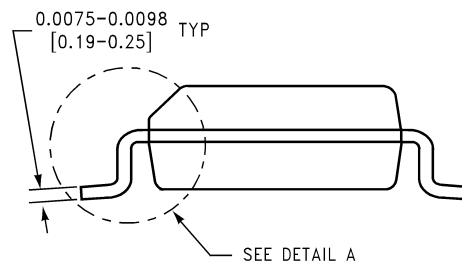
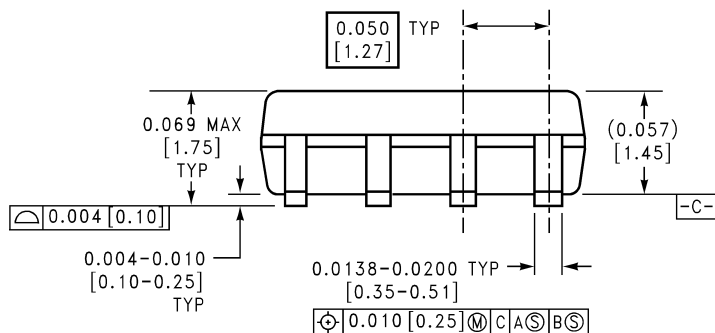
DS101055-27

**Physical Dimensions** inches (millimeters) unless otherwise noted



DETAIL A  
TYPICAL SCALE: 40X

DIMENSION IS INCH  
VALUES IN [ ] ARE MILLIMETERS



For Order Numbers , see Ordering Information Table  
NS Package Number M08A

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